Skin-Friction Measurements on a Rotor in Hover

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A means of acquiring skin-friction measurements on a fixed wing using an oil-flow interferometric technique was developed at Ames in the early 1990s. As long as flow conditions are steady, as they are in hover, this technique can be applied to rotary wings also. During the March 1997 hover test of a full-scale XV-15 tiltrotor in the Ames 80- by 120-Foot Wind Tunnel, this technique was used for the first time to provide detailed skin-friction measurements on a rotor over a wide range of thrust conditions.

The method consists of applying a highly reflective adhesive-backed Mylar film to the rotor blade at each radial station of interest. Six radial stations were chosen for this study: 17%, 28%, 50%, 72%, 83%, and 94% of the rotor radius. To determine the *chordwise* shear stress at a desired location, oil is applied to the Mylar film in a thin line oriented parallel to the blade leading edge. Centrifugal force will act parallel to this radial oil line and therefore play no role in the chordwise development of the oil film.

The first part of the figure represents the initial pattern of oil lines applied to the rotor blade at the 72%-radius location. The lines are staggered in an attempt to prevent adjacent oil films from merging with each other. Also visible is a series of chordwise oil lines applied with the objective of measuring the radial shear stress. The rotor is rapidly spun up and held "on condition" for several minutes before quickly being brought to rest. If the oil films are subsequently photographed using monochromatic light, a series of fringe patterns is made visible, as shown in the second part of the figure. Each fringe pattern provides information about the local oil-film thickness distribution, and this in turn yields a measurement of shear stress. The third part of the figure presents corresponding measurements of the chordwise component of skin friction at the radial station r/R = 72% (where R is the rotor tip radius and r is the radial station) under nominal 1-g hover conditions (coefficient of thrust $C_T = 0.0093$) at design tip Mach number 0.69. Shear stress is directly proportional to fringe spacing, and this latter part of the figure clearly indicates the increase in shear stress associated with the transition from laminar flow to turbulent flow.

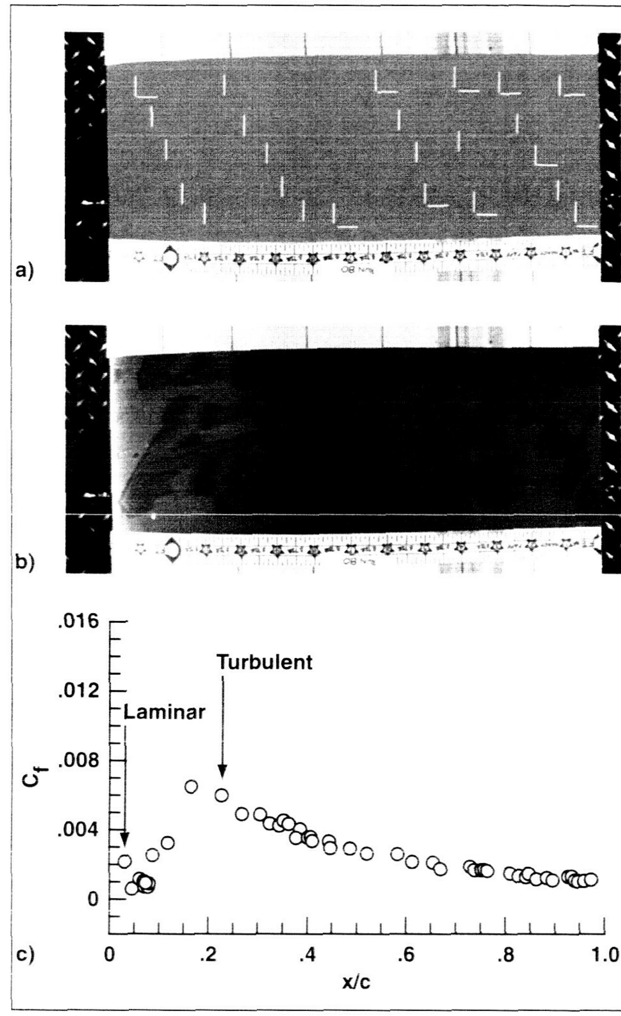

Fig. 1. (a) Initial oil-line pattern; (b) final oil-film pattern; and (c) chordwise skin-friction coefficient for nominal 1-g hover conditions at r/R = 72%.

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